9th International Forum on Engineering Decision Making Resilient Infrastructures - Integration of Risk and Sustainability December 7 – 10, 2016 Stoos, Switzerland



STRUCTURED EXPERT JUDGMENT FOR DEPENDENCE MODELLING APPLIED TO THE SELECTION OF INDICATORS OF INFRASTRUCTURE RESILIENCE

Maria Nogal & Alan O'Connor







THE UNIVERSITY OF DUBLIN



Resilience: Ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events [National Academy of Sciences (2012)].

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What do we understand by resilience?

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Intensity of impact







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Dynamic problem





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QUALITATIVE & SEMI-QUALITATIVE METHODS

- Indices that rely on subjective assessments (e.g., diversity or adaptability).
- Indicators quantifying system attributes (e.g., reliability), which <u>are assumed to</u> <u>be related</u> to the resilience of the system.
- / Identification of the system weaknesses and the resilience enhancement opportunities, but not objective.

[1] Nogal, M. and O'Connor, A. (2017). Risk and Resilience (in press). Springer, Chapter Cyber-Transportation Resilience. Context and methodological framework, 1–10.

[2] Nogal, M., O'Connor, A., Caulfield, B., & Martinez-Pastor, B. (2016). Resilience of traffic networks: From perturbation to recovery via a dynamic restricted equilibrium model. Reliability Engineering & System Safety, 156, 84-96.



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QUANTITATIVE METHODS

- Performance-based methods: performance of a system in a particular disturbing scenario ([2]).
- / Framework to objectively compare different cases, nevertheless with a less holistic view.

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Goal & Challenges

GOAL: To assess the resilience of a system through indicators quantifying system attributes, which **are related** to the resilience of the system.





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Goal & Challenges

GOAL: To assess the resilience of a system through indicators quantifying system attributes, which **are related** to the resilience of the system.



What does resilience depend on? Selection of a list of indicators that, when combined, explain a high percentage of the system resilience.



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Goal & Challenges

GOAL: To assess the resilience of a system through indicators quantifying system attributes, which **are related** to the resilience of the system.



What does resilience depend on? Selection of a list of indicators that, when combined, explain a high percentage of the system resilience.

2 How can their contribution be assessed? Removing possible information overlapped.





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Goal & Challenges

GOAL: To assess the resilience of a system through indicators quantifying system attributes, which **are related** to the resilience of the system.



What does resilience depend on? Selection of a list of indicators that, when combined, explain a high percentage of the system resilience.





Can any mathematically-quantifiable indicator be used as a systematic framework to assess the resilience?







To model the dependence among the indicators, and between indicators and resilience







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To model the dependence among the indicators, and between indicators and resilience

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To identify the subspace of possible dependence structures



RAIN How to address the problem



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To model the dependence among the indicators, and between indicators and resilience

To identify the subspace of possible dependence structures

Statistical samples of joint observations of realisations





Conclusions



To model the dependence among the indicators, and between indicators and resilience

To identify the subspace of possible dependence structures

Statistical samples of joint observations of realisations

To ask experts about dependence structures

Structured Expert Elicitation has been used in many topics, such as climate change, volcanic eruptions, air transport safety, and sea level rise. Therefore it seems to be a suitable approach to investigate the resilience.



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Structured expert judgment for dependence modelling



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Expert elicitation: process of **synthesis of subjective judgments of experts** on a subject where there is uncertainty due to insufficient data because of physical constraints or lack of resources.

"Structured" Expert Elicitation: the process is based on structured protocols to reduce potential sources of bias and error among experts.

Types of SEE

- Behavioural looks for the consensus among experts, who are typically encouraged to interact and share their assessments (*Delphi method*).
- Mathematical deals with individual assessments, combine them mathematically after their elicitation. They yield more accurate results (Cook's method).





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Proof of Concept



Case study - Irish Road network

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Intrinsic vulnerability: susceptibility to incidents characterised by their random occurrence in space and time that can result in considerable reduction or loss of the functionality.

Indicators: Reliability & accessibility.

ELIC	ELICITATION OF DEPENDENCE MODELLING														
Calibration Variables		Variables of Interest (percentile 50)													
Calibration variables		ODs	$Prob(V_{i,j} A_{i,j})$	$Prob(V_{i,j} A_{i,j},R_{i,j})$											
$Prob(A_{25,69} A_{32,92})$	0.499	20-25													
$Prob(A_{32,92} A_{69,92})$	0.455	25-69													
$Prob(A_{25,69} A_{32,92},A_{69,92})$	0.500	32-69	32-69 Unknown values												
$Prob(R_{25,69} R_{32,92})$	0.575	32-92													
$Prob(R_{32,92} R_{69,92})$	0.871	69-92													
$Prob(R_{25,69} R_{32,92},R_{69,92})$	0.563														





Elicitation process





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- Reliability and accessibility are both valid indicators to assess the intrinsic vulnerability of the network.
 - Other indicators are required to explain a high percentage of the vulnerability.
 - The most vulnerable ODs can be identified.



Nogal, M., Morales-Napoles, O. and O'Connor, A. Understanding the vulnerability of traffic networks by means of structured expert judgment elicitation. Reliability Engineering & System Safety, (submitted).



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- This approach can be used to identify the most relevant indicators to be considered when assessing those descriptors, and their contribution.
- Moreover, the methodology will allow quantitative approaches, rather than the so common qualitative or semi-qualitative methods.
- Experts usually expressed themselves more confident in assessing the dependence relation between variables, rather than estimating the uncertainty distribution of the variables.





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Fri, 24 March 2016, 10:00 - 17:00 Printing House, Trinity College Dublin - Ireland

Save the date for the RAIN Final Event

RAIN

Practical information All presentations and discussions will be in English. For registration and info please contact Maria Nogal rain.project.eu.fp7@gmail.com +353 1 896 3199.

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MANY THANKS FOR YOUR ATTENTION

 Maria Nogal
 nogalm@tcd.ie

 Alan O'Connor
 oconnoaj@tcd.ie

 Oswaldo Morales-Napoles
 o.moralesnapoles@tudelft.nl

http://rain-project.eu/